TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 697

THE D.V.L. GLIDING-ANGLE CONTROL (W. HÜBNER DESIGN)

By Walter Hübner and Wilhelm Pleines

Zeitschrift für Flugtechnik und Motorluftschiffahrt
Vol. 23, No. 15, August 12, 1932
Verlag von R. Oldenbourg, München und Berlin

Washington
January, 1933

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM NO. 697

THE D.V.L. GLIDING-ANGLE CONTROL (W. HÜBNER DESIGN)*

By Walter Hübner and Wilhelm Pleines

DESCRIPTION OF ANGLE OF GLIDE RUDDER

Aerodynamic Principles

It is possible to increase the gliding angle of an airplane by increasing the parasite drag, by the extension or rotation of wing brakes. The rise in drag coefficient attainable by this method is practically constant for all angles of glide, whereas the total drag coefficient rises considerably with the angle of attack. Consequently, decelerating surfaces of this kind yield, even if of large dimensions, perceptible variations in gliding angle only at low but not at the large angles of attack.

However, it is more apposite to change the induced drag of the airplane, especially of the wing, than the parasite drag. The induced drag of a wing is dependent on the distribution of the lift along the span. Deviations of this distribution from the form of a semi-ellipse result in a greater drag coefficient which increases with the angle of attack. Consequently, a variation in lift distribution over the span needs to make it possible to change the induced drag and through it the gliding angle of an airplane.

The lift distribution can be changed by disturbing the smooth flow at isolated points on the top side of the wing. The point of the disturbance must be so chosen as not to vitiate the stability and controllability of the airplane. In other words, the flow on the wing at the part of the surface lying in front of the horizontal tail group and in the range of the ailerons must not be disturbed.

*"Das DVL- (Deutsche Versuchsanstalt für Luftfahrt) Gleitwinkelsteuer (Bauart W. Hübner). Z.F.M., August 12, 1932, pp. 455-459.

Local interferences may be introduced, say, by slots in the wing, opening in longitudinal direction. But they could hardly be fitted in already built airplanes, apart from the interruption of the distortion bond of the wing which would result.

A simpler way would be to use wing brakes which are rotated about axes identical with the lateral axis of the airplane or else so extended as to be perpendicular to the direction of flight in extended position. But with the customary wing arrangements such surfaces vitiate the stability about the normal axis, aside from the danger which exists that the flow would periodically become separated on them.

These errors can be avoided by the use of rudders (wing brakes) on the top of the wing which are so rotated about axes perpendicular to the wing as to bring the cut of the extension of the planes of the rudders in front of the wing. (See fig. 4.) Thus, when extended, the wing rudders form an angle of less than 90° with the direction of the air flow. In that manner the point of the separation of flow is definitely established and cannot change from one rudder edge to the other. Besides, such rudders result in increased rather than decreased stability about the normal axis.

With a view to manipulation in flight, a device for changing the gliding angle must be designed as control mechanism and not as switch mechanism. The pilot must be in the position of handling the angle of glide rudder just as delicately and appropriately as the other airplane controls. The displacement must be amenable to steady and arbitrary variations; changes in angle of displacement must be felt as moments - comparable to the displacement - about the rudder axis and on the lever. After release of the lever the surfaces under the effect of the aerodynamic forces must automatically return to their original position, i.e., the position of minimum drag. Thus, a device for changing the gliding angle could comprise several rudders so disposed on the upper side of the wing as to bring their axes of rotation perpendicular to the plane of the wing. In neutral position the rudders face in the direction of flow* and offer very little resistance. To

*Basically, however, the rudder was to be closed, that is, so as to be operable in any desired position by the pilot, even if there are no aerodynamic moments about the rudder axis.

avoid disturbance of the stability and the controllability the rudders are fitted at that part of the wing lying between the aileron and the zone in front of the horizontal tail surfaces. The axis of the rudder must, in order to obtain a steady increase in rudder moment with the displacement, lie ahead of the first fourth of the rudder chord. The magnitude of the resultant forces can be changed at random by the selection of the position of the axis with respect to the rudder.

It would be feasible to have the axis of such a rudder in practically the same direction as the lateral airplane axis, but then the wing rudder, even when extended, would not be perpendicular to the direction of the air flow.

It further is possible to so design the rudders serving for displacement, as to ensure movement in opposite as well as in the same sense. Then they can be used, in addition, to obtain a side slip. Independent actuation of the rudders on both wing-halves would obtain to support or substitution of the conventional rudder and aileron control.

Description of the Device (Examined Type)

The D.V.L. developed such an angle of glide rudder and mounted it on a BFW-M 23b low-wing monoplane. The rudders, made of duralumin, were of symmetrical section, their axis of rotation being parallel to the normal axis of the airplane. (Figs. 1 and 2.) The pivoting axis of each rudder lies directly on the leading edge, ensuring a wind-vane effect when the lever is released. In view of the low control forces in this particular case it was not deemed necessary to attempt an obtainable aerodynamic balance of the rudder moments by backward displacement of the pivoting axis. The rudders are therefore fitted at a part of the wing (fig. 3) which is neither in front of the tail group nor of the aileron and outside of the propeller slipstream.

Owing to the special static design of the wing (one spar with torsion-resistant wing nose), the pivoting axis could not, as originally intended, be placed directly adjacent to the nose, but had to be placed aft of the wing spar. This location perhaps does not ensure the most desirable effect, namely, complete separation of flow at this part of the wing.

The pivoting axes extend through the wing, linked at the bottom side to pulleys and cables and coupled to a control lever at the left side in the cockpit. A pull on this lever actuates the two rudders in different directions, though through the same angle. The cables being provided with returns the rudders can be reset to neutral by pushing the lever forward. The choice of directional rotation of the rudders outward avoids a decrease in stability about the normal axis. Figure 4 is a diagrammatical sketch of the mechanism.

Since the rectangular controls do not fair into the cambered top side of the wing at every angle of displacement, the separation of flow could but be incomplete. This was overcome by inserting a strip of sheet metal, freely pivoting about a hinge and slidable in a slot, in each rudder. The lower edge of this loosely suspended metal, tipped with a rubber strip, rests consistently on the wing. (Figs. 1 and 2.)

The observation of the flow (wool tufts) during the first test flights revealed the absence of any disturbance or change in flow about this range of the wing when the rudders were set neutral. From that it could be concluded that the rudders in initial setting produce no perceptible deterioration of the aerodynamic quality of the airplane.

Even with fully extended rudders the separation was confined to one small zone, whose width was far from corresponding to the chord of the rudder surface, 40 cm (15.75 in.). This fact brings out that an improved effect could be obtained by the following arrangement (b_2). On the inside of the rudder, in neutral setting, a solid fairing conforming to the outside shape of the rudder, is attached. (Compare Figs. 1 and 2.) Then when the rudders are displaced they form between themselves and the stationary metal fairing an increasing acute angle whose inside space is not accessible to direct pressure equalization. The result is complete separation of flow, at least at that part of the wing lying behind this segment, as subsequently proved by the flow pictures.

TEST RESULTS AND PRACTICAL FLIGHT EXPERIMENTS

The Tests

The airplane used in these experiments was a BFW-M 23 fitted with an Argus As 8 engine. (Fig. 3.) The flight tests were made with the same gross weight (G = 620 kg (1,367 lb.)) and c.g. position, consisting of glides with throttled engine at different speeds, that is,

a, angle of glide rudder in neutral position

b_1, (form b_1) fully displaced

b_2, (form b_2) fully displaced

The comparative measurements were made in gliding flights at constant dynamic pressure at practically the same height stages (between 500 m (1,640 ft.) and 800 m (2,625 ft.)). The variation in air pressure with the time was recorded on the Askania altitude recorder (revolution of recording drum 4 min.). The actual dynamic pressure was determined from the record of the dynamic pressure indicator in speed calibration flights over a square course.

Figure 5 is a record of the time rate of change in air pressure at various flight speeds and for a) neutral, and b) fully displaced wing rudders. The records give a qualitative picture of the efficacy of the device with regard to enhanced gliding by the same flying speed.

Interpretation and Test Data

From the aforementioned records the momentary sinking speed v_s was determined. (For detailed description of interpretation method, see D.V.L. Yearbook 1931, p. 694.)

The results of the glide measurements are graphed in Figure 6, which shows v_s plotted against the true flying speed v for various displacements and arrangements of the angle of glide rudder. It is seen from this graph that the influence of this device is considerable on the enlargement of the total drag and particularly on the induced drag. For equal flight speed of, say, 90 km/h (56 mi./hr.) the sinking speed, by fully deflected wing rudder and with arrangement b_1, increases by more than 50 per cent, with arrangement b_2 by about 60 per cent. As the flying speed increases, so the difference becomes greater, especially for the modified arrangement (attitude b_2) as seen from Table I.

TABLE I. Increase in Sinking Speed v_s in per cent

Gliding speed v km/h	Wing-rudder arrangement b_1	b_2
90.0	~ 54	~ 60
120.0	~ 54	~ 78
150.0	~ 49	~ 68

km/h × .62137 = mi./hr.

TABLE II. Change of Gliding Angle

Speed of glide v km/h	Angle of gliding φ (degrees) and airplane attitude			Enlarged gliding angle in % with	
	a normal	Rudder arrangement b_1	b_2	b_1	b_2
90.0	7.7°	12.5°	12.8°	~ 61	~ 65
120.0	8.7°	13.5°	15.4°	~ 54	~ 76
150.0	10.8°	16.0°	18.2°	~ 50	~ 70

The above table gives the average differences in gliding angle φ versus flight speed v for different wing rudder setting and arrangement.

Arrangement b_2 is in every case within the scope of the experiments superior to b_1, though the best efficiency of arrangement b_1 lies at lower gliding speeds (v = ~ 90 km/h (56 mi./hr.)) than with arrangement b_2 (v = ~ 120 km/h (74.8 mi./hr.)), with the result that b_1 comes closer to the desired aim, i.e., maximum gliding angle precisely in the range of customary landing speeds. To be sure, no attempt was made to analyze the effect which a changed location of the wing rudder along the wing chord has on the efficiency. As regards the choice of location, one can therefore merely say that the efficiency probably becomes so much better as the rudder is placed farther toward the leading edge of the wing.

The inevitable drop in maximum lift resulting from displacing the wing rudder is, as fas as the flight tests reveal, comparatively small.

The same effect as with arrangement b_2 can presumably also be obtained with arrangement b_1 by enlarging the chord.

In Figure 7 the gliding ratio $1/\epsilon$ is plotted against flight speed v for the different wing-rudder arrangements, whereas Table III contains the mean values of the differences of the individual gliding distances. According to it there is an almost constant shortening of distances at all flying speeds in gliding flight of about 35 per cent when the wing rudders are fully extended conformable to arrangement b_1 and more than 40 per cent for arrangement b_2.

TABLE III. Shortened Gliding Distance

Speed of glide v km/h	Glide (m) from 100 m height by attitude			Shortened gliding distance in per cent by	
	a	b_1	b_2	b_1	b_2
90.0	735	475	440	35	40
120.0	650	420	370	35	43
150.0	525	345	300	34	43

To illustrate the effect of the D.V.L. angle-of-glide rudder on the shortened landing run, Figure 8 shows the landing process by a simple landing path. The airplane assumedly glides in to land from 100 m (328 ft.) altitude at equal path velocity, v = 90 km/h (56 mi./hr.), but different sinking speeds, corresponding to the position and arrangement of the wing rudders. The angle of attack of the airplane is to be the same in all three cases (a, b_1, b_2) at the instant the airplane touches the ground. This presumption is practically given, because the glide with fully deflected wing rudder can be followed up with the otherwise customary flattening-out process, as soon as these rudders are set to neutral when within a few meters from the ground. The sinking speed and forward speed are then the same in all three cases at the moment of touching the ground. The then also identical taxying distance can be assumed at around 200 m (656 ft.), according to previous measurements. The difference in total landing run from a given height is exclusively due to the difference in the momentary gliding distance. (Fig. 8.)

Practical Flight Experiments

As concerns the practical manipulation and proof of the examined angle-of-glide rudder, the following may be said. Upon release of the lever in the pilot's cockpit the wing rudders automatically face into the wind. The control forces are, apart from the friction - the bearings are plain bearings - within practically acceptable limits. The maximum forces for complete displacement are no greater than usual, considering the time period within which this flight attitude must be maintained while gliding in to landing. For the rest, it may be averred that the control forces for actuating this or a similar angle-of-glide rudder, can in any case be kept at a minimum by appropriate selection of force transmission system and bearings.

The incipient rise in sinking speed upon displacement of the wing rudder is perceptibly felt, though the changes in acceleration produced at the moment the effect commences as a result of the change in flight path, is at no time disagreeable even by sudden displacement. When these rudders were completely extended the airplane changed to a higher dynamic pressure by equal elevator displacement. The load changes attributable to change and disturbance of moment equilibrium which, moreover, caused only a slight nose heaviness and a new equilibrium position coordinated to the same elevator displacement at a 15 to 20 km/h (9.3 to 12.4 mi./hr.) higher dynamic pressure, are wholly within acceptable limits.

Upon release of the lever the effect soon stops. This fact makes it possible to maintain the effect of such rudders when gliding in to land within a few feet above the ground and then level out in the usual manner by suddenly releasing the lever.

The flight characteristics are not affected disadvantageously, either in level or in curved flight. The consensus of the different pilots who have flown the airplane with this device is uananimous and thus confirms the results of the tests.

SUMMARY

The report describes a device for arbitrary enlargement of the gliding angle of airplanes, especially of such with flat gliding angle and difficult landing characteristics. The D.V.L. gliding angle control (design, Hübner) permits a local interruption of the lift distribution along the span and consequently an increased induced drag.

The mechanism comprises two wing rudders operated by lever from the pilot's cockpit. Said rudders are fitted on the top side of the wing near the leading edge. The displacement of these rudders results in a separation of the air flow on the top side of the wing. In neutral setting these rudders face into the wind. The device was mounted on a BFW-M 23 b airplane and tried out in gliding tests. For equal flight speed the enlarged gliding angle amounted to more than 60 per cent for fully extended wing rudders, or, a more than 40 per cent shorter gliding distance for this particular airplane.

The device is fundamentally proved true. It is readily installed on any type of airplane, in which an arbitrarily increased gliding angle is desired to facilitate landing.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

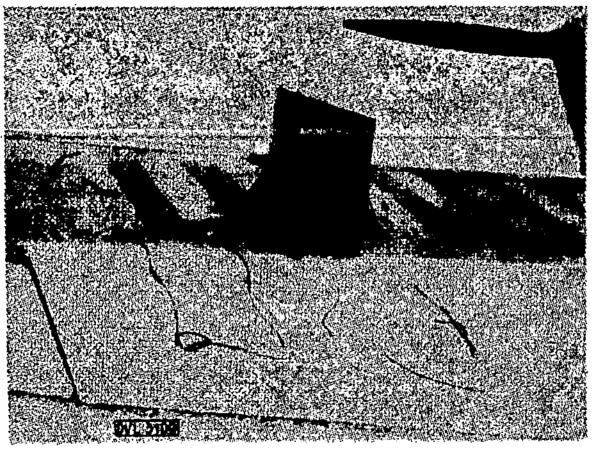

Fig.1 Design and mounting of one wing rudder (b_1) on a BFW-M 23b in neutral setting. Dimensions: height 0.15 m (.49 ft.), depth 0.14 m (.46 ft.). Total resistance area for both rudders extended, 0.12 m^2 (1.29 sq.ft.) (Total wing area 14.2 m^2), (152.85 sq.ft.)

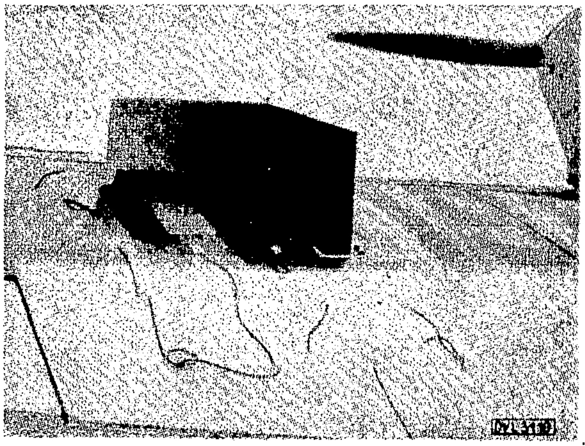

Fig.2 Design and mounting of one rudder (b_1), displaced at 80°. Note the fixed guide plate (design b_2) at the right.

Fig.5 Comparative record of time rate of change of air pressure at different equilibrium-dynamic pressures.

a , Neutral
b , (Design b_1) fully extended
q_1, 102 km/h (63.4 m.p.h.)
q_2, 130-132 km/h (80.8 - 82.0 m.p.h.)
q_3, 115-117 km/h (71.5 - 72.7 m.p.h.)

a, (Design b_1) neutral setting
b, (Design b_1) fully extended

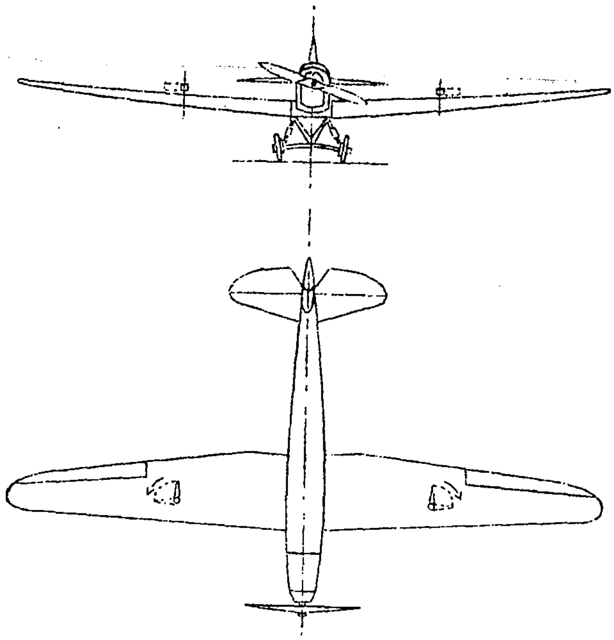

Fig.3 View of BFW-M23b with wing rudders installed.

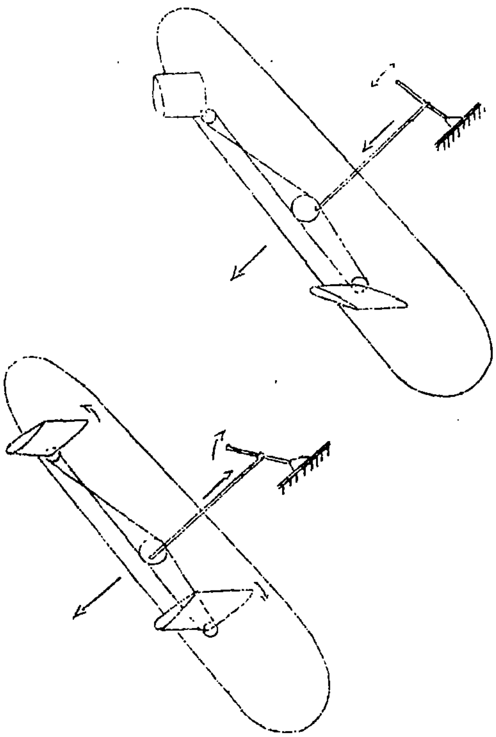

Fig.4 Wing-rudder assembly.

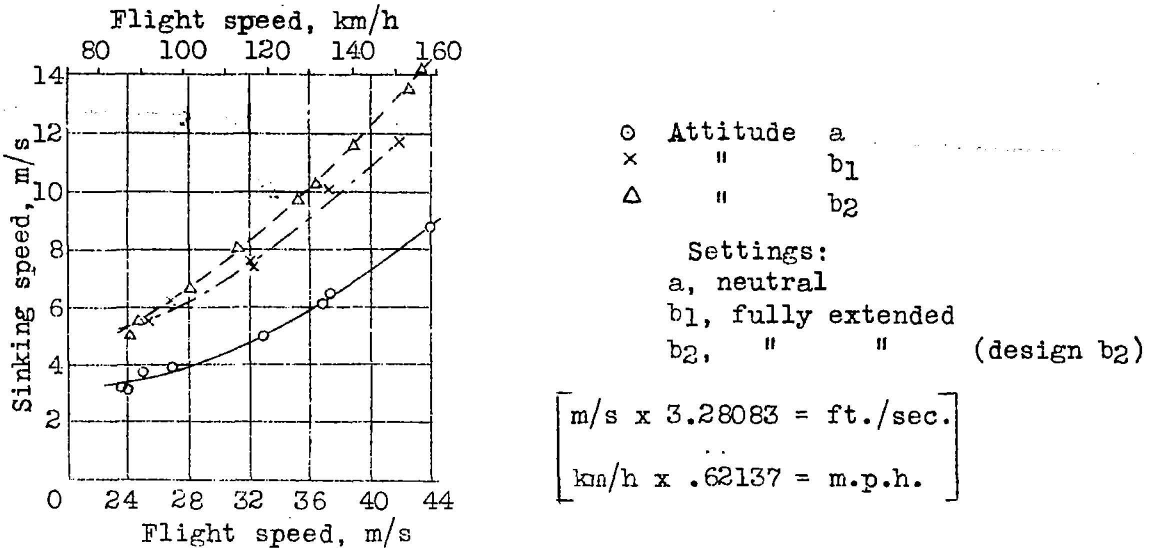

Fig. 6 Sinking speed versus flight speed with different wing-rudder settings.

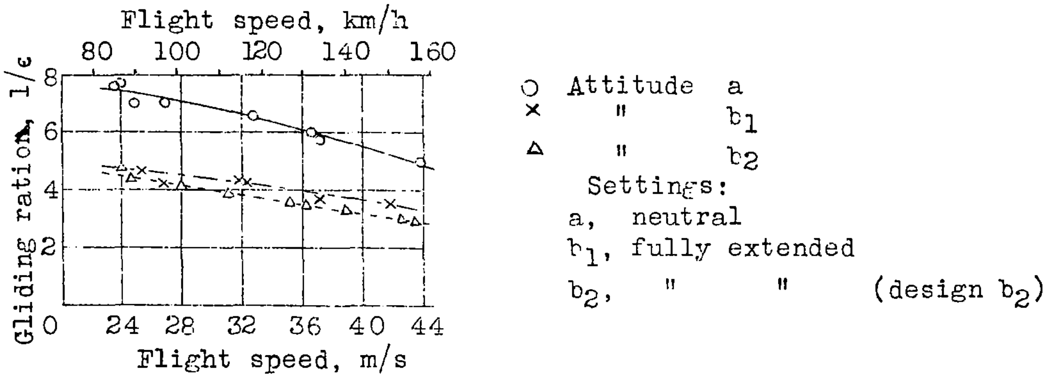

Fig. 7 Gliding ratio versus flight speed.

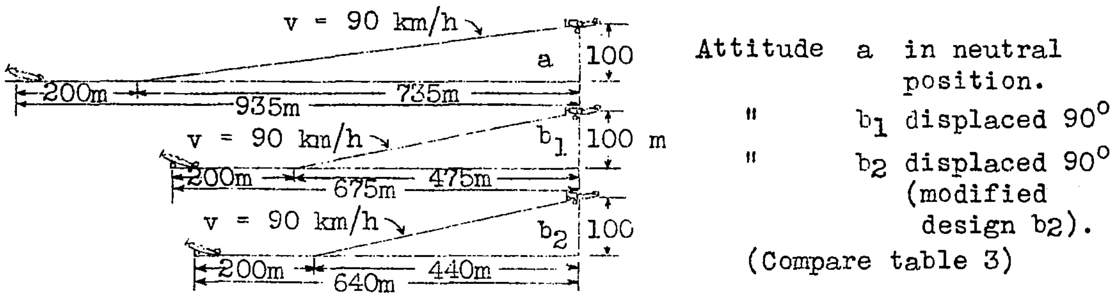

Fig. 8 Comparison of effect of DVL angle of glide rudder on shortened gliding distance from a stated height and with same gliding speed (v = 90 km/h).